

Markscheme

May 2016

Chemistry

Higher level

Paper 3

27 pages

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Subject Details: Chemistry HL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A [**15 marks**] and all questions from **ONE** option in Section B [**30 marks**].
Maximum total = [**45 marks**].

1. Each row in the “Question” column relates to the smallest subpart of the question.
2. The maximum mark for each question subpart is indicated in the “Total” column.
3. Each marking point in the “Answers” column is shown by means of a tick (✓) at the end of the marking point.
4. A question subpart may have more marking points than the total allows. This will be indicated by “**max**” written after the mark in the “Total” column. The related rubric, if necessary, will be outlined in the “Notes” column.
5. An alternative word is indicated in the “Answers” column by a slash (/). Either word can be accepted.
6. An alternative answer is indicated in the “Answers” column by “**OR**”. Either answer can be accepted.
7. An alternative markscheme is indicated in the “Answers” column under heading **ALTERNATIVE 1** etc. Either alternative can be accepted.
8. Words inside chevrons « » in the “Answers” column are not necessary to gain the mark.
9. Words that are underlined are essential for the mark.
10. The order of marking points does not have to be as in the “Answers” column, unless stated otherwise in the “Notes” column.
11. If the candidate’s answer has the same “meaning” or can be clearly interpreted as being of equivalent significance, detail and validity as that in the “Answers” column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by **OWTTE** (or words to that effect) in the “Notes” column.
12. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

13. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script.
14. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the “Notes” column.
15. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the “Notes” column. Similarly, if the formula is specifically asked for, do not award a mark for a correct name unless directed otherwise in the “Notes” column.
16. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected. Do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the “Notes” column.
17. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the “Notes” column.

Section A

Question			Answers	Notes	Total
1.	a		<p>Ozone: yes because it absorbs IR/is IR active ✓</p> <p>Oxygen: no because it does not absorb IR/is IR inactive ✓</p>	<p><i>Award [1 max] for stating “ozone/O₃ is a greenhouse gas but oxygen/O₂ is not”.</i></p> <p><i>Award [1 max] for stating “ozone/O₃ absorbs IR/is IR active but oxygen/O₂ does not/is IR inactive”.</i></p> <p><i>Accept “oxygen/O₂ is not a greenhouse gas because it absorbs UV”.</i></p>	2
1.	b	i	<p>Any value or range within the range: 1300–1500 «km mol⁻¹» ✓</p>	<p><i>(It is in fact 1403 «km mol⁻¹» using the same measurement technique as that used to get the data in the table).</i></p>	1

(continued)

Question			Answers	Notes	Total
1.	b	ii	<p>CCl_4 is symmetrical/dipoles of C–Cl bonds cancel out OR C–F bond more polar «than C–Cl bond» ✓</p> <p>«vector» sum of bond polarities in CCl_3F non-zero/greater OR dipoles of «three» C–Cl bonds do not cancel the dipole of the C–F bond ✓</p>	<p>Accept suitable diagrams with dipoles represented as vectors illustrating M1 and/or M2.</p> <p>Accept “fluorine/F more electronegative «than chlorine/Cl»” for M1.</p> <p>Accept converse statements throughout. Accept “dipoles will not cancel out in CCl_3F” for M2.</p>	2
1.	b	iii	<p>GWP increases as IR intensity increases ✓</p>	<p>Accept “GWP proportional to IR intensity”. Accept “there is a positive correlation/relationship”. Accept converse statement.</p>	1
1.	b	iv	<p>no relationship AND CO_2 and CCl_4/CF_4 are non-polar/have zero dipole moment «but» have very different integrated IR intensities OR no relationship AND CCl_2F_2 and CClF_3 have «almost» the same dipole moment but have very different integrated IR intensities OR no relationship AND sometimes there is a positive relationship between the two «variables» and sometimes there is a negative/no relationship between them OR no relationship AND as F atoms are «gradually» added to CCl_4, integrated IR intensity always increases while dipole moment increases and then decreases ✓</p>	<p>Accept a plot or sketch with a comment that “changes along x-axis produce random changes along y-axis”. Accept “yes there is a relationship, as there is still a weak overall «statistical» positive correlation”. Accept “dipole” for “dipole moment”.</p>	1

(continued)

Question			Answers	Notes	Total
1.	b	v	<p>«data from table such as integrated IR and GWP indicate that they» contribute significantly to global warming/enhanced greenhouse effect ✓</p> <p>cause ozone depletion OR chlorine/Cl released when exposed to ultra-violet/UV «radiation» ✓</p>	<p><i>Do not just accept “contributes to global warming” without an indication that the effect is large.</i></p> <p><i>Do not accept just “contributes significantly to climate change”.</i></p> <p><i>Award [1 max] for “persistent in atmosphere”.</i></p> <p><i>Accept a consequence of global warming for M2.</i></p>	2
2.	a		<p><i>Key Procedural Steps:</i></p> <p>use volumetric flask ✓</p> <p>mix the solution ✓</p> <p>fill up to line/mark/«bottom of» meniscus/1 dm³ «with deionized/distilled water» ✓</p> <p><i>Key Technique Aspects:</i></p> <p>use balance that reads to two decimal places/use analytical balance/use balance of high precision ✓</p> <p>mix pellets in beaker with deionized/distilled water «and stir with glass rod to dissolve» ✓</p> <p>use a funnel «and glass-rod» to avoid loss of solution ✓</p> <p>need to rinse «the beaker, funnel and glass rod» and transfer washings to the «volumetric» flask ✓</p> <p><i>Safety Precautions:</i></p> <p>NaOH corrosive/reacts with water exothermically ✓</p> <p>keep NaOH in dessicator ✓</p> <p>let the solution cool ✓</p>	<p><i>Two marks may be awarded from two different categories or from within one category.</i></p> <p><i>Do not accept “use of a funnel to transfer the solid”.</i></p> <p><i>Do not accept “keep volumetric flask in cold water/ice”.</i></p>	2 max
2.	b	i	blue to green/yellow ✓		1

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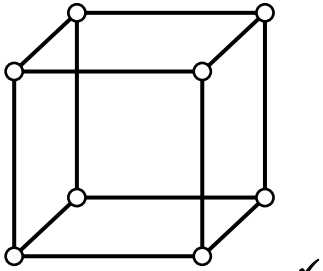
Question			Answers	Notes	Total
2.	b	ii	equivalence point has been exceeded OR greater volume of/too much acid has been added ✓ «calculated» concentration increased ✓	Accept “end-point” for “equivalence point”.	2
2.	c		colour difficult to detect OR used different HCl standards OR no significant figures used in subsequent calculation OR incorrect method of calculation ✓	Accept any valid hypothesis. Do not accept any mistakes associated with technique (based on stem of question) eg. parallax error, not rinsing glassware, etc. Do not accept “HCl was not standardized”. Accept “reaction of NaOH with CO ₂ «from air»”. Accept “NaOH hygroscopic/absorbs moisture/H ₂ O «from the air/atmosphere»”. Accept “impurities in NaOH”. Accept “temperature changes during experiment”. Ignore a general reference to random errors.	1

Section B

Option A — Materials

Question			Answers	Notes	Total
3.	a		$\text{Fe}_2\text{O}_3(\text{s}) + 3\text{CO}(\text{g}) \rightarrow 2\text{Fe}(\text{l}) + 3\text{CO}_2(\text{g})$ ✓		1
3.	b		<p>Fe_2O_3: paramagnetic AND unpaired electrons present «so magnetic moments do not cancel out» ✓</p> <p>Al_2O_3: diamagnetic AND no unpaired electrons/all electrons are paired «so magnetic moments cancel out» ✓</p>	<p>Award [1 max] for “Fe_2O_3 paramagnetic AND Al_2O_3 diamagnetic”.</p> <p>Award [1 max] for “Fe_2O_3 unpaired electrons present AND Al_2O_3 no unpaired electrons/all electrons are paired”.</p> <p>Award [1 max] for “Magnetic moments do not cancel out in Fe_2O_3 but do in Al_2O_3”.</p> <p>Unpaired and paired electrons may also be conveyed by orbital diagrams for the respective ions.</p>	2
3.	c		<p>$n(\text{e}) = \frac{2.00 \times 10^6}{96500} / 20.7 \text{ «mol»}$ OR $n(\text{Al}) = \frac{1}{3} n(\text{e}) / 6.91 \text{ «mol»}$ ✓ $m(\text{Al}) = \text{«}6.91 \times 26.98 \text{ »}186 \text{ «g»}$ ✓</p>	Award [2] for correct final answer for any value within the range 186–189 «g».	2

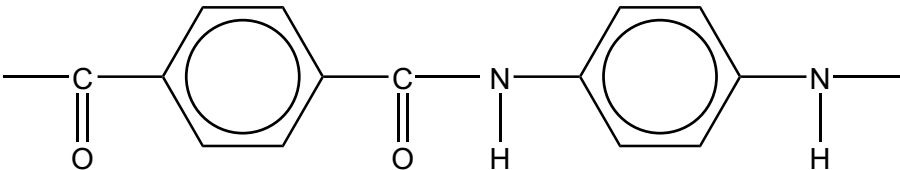
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Question			Answers	Notes	Total
3.	d	i	collisions between electrons AND positive ions/cations/metal atoms/metal lattice ✓	Accept “irregularities/non-uniformity in metal lattice «caused by impurities» but do not accept just “impurities present”. Do not accept “attractions” for “collisions”.	1
3.	d	ii	metal II is a <u>superconductor</u> ✓ passing electrons «slightly» deform lattice/displace positive ions/cations AND couple/form Cooper pairs/condense with other electrons ✓ energy propagates along the lattice in wave-like manner/as phonons ✓ Cooper pair/electron condensate moves through lattice freely OR phonons are «perfectly» elastic/cause no energy loss ✓		3 max
3.	e	i	 ✓ «coordination number =» 6 ✓	Do not accept diagram of a lattice showing multiple unit cells.	2
3.	e	ii	«Bragg equation, $n = 1$ » $d = \frac{8.80 \times 10^{-11}}{2 \times \sin(13.0)} = 1.96 \times 10^{-10} \text{ «m» } \checkmark$		1

(continued)

Question			Answers	Notes	Total
4.	a		possible toxicity «of small airborne particles» OR unknown health effects OR small particle size «and large surface area» may increase reaction rate to dangerous levels OR immune system/allergy concerns OR uncertain impact on environment ✓	<i>Accept specific health effect (eg. may cause cancer/effect on respiratory system, etc).</i>	1
4.	b		pores/cavities/channels/holes/cage-like structures «in zeolites» have specific shape/size ✓ only reactants «with appropriate size/geometry» fit inside/go through/are activated/can react ✓		2
4.	c		<i>Catalyst:</i> iron/Fe OR iron«0» «penta» carbonyl/Fe(CO) ₅ ✓ <i>Conditions:</i> high temperature/any value or range within the range 900–1600 °C AND high pressure/any value or range within the range 10–100 atm ✓	<i>Accept “cobalt-molybdenum/Co-Mo/CoMo”.</i> <i>Accept high pressures expressed in kPa/Pa.</i>	2

(continued)

Question			Answers	Notes	Total
5.			ceramics have «giant» ionic/covalent/ionic AND covalent structures ✓ metals contain lattice of positive ions/cations in sea of delocalized electrons ✓	Accept [1 max] for “ionic/covalent/ionic and covalent bonds in ceramics AND metallic bonds in metals”. Accept suitable diagram for M2.	2
6.	a		«CN group makes» molecule polar ✓ alignment/orientation of molecules can be controlled by electric field OR allows molecules to align in an electric field/when a voltage is applied ✓	Accept “CN is polar”.	2
6.	b	i	 / —COC ₆ H ₄ CONHC ₆ H ₄ NH— ✓	Continuation bonds are necessary for the mark but brackets and n can be ignored. If more than one repeating unit is drawn, do not award the mark.	1
6.	b	ii	H bonds «form between chains from NH of one chain to CO of the next» ✓		1

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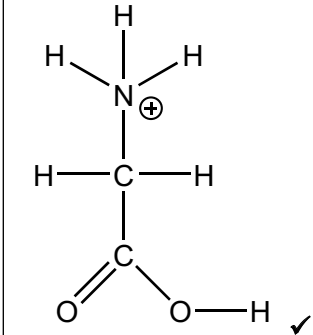
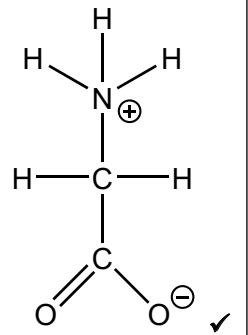
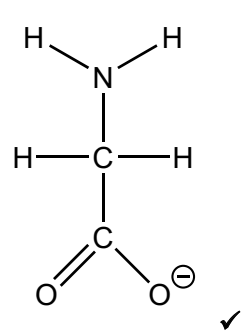
Question			Answers	Notes	Total
7.	a		<p>«plasticizer molecules» fit between chains OR «plasticizer molecules» prevent chains from forming crystalline regions OR «plasticizer molecules» keeps strands/chains/molecules separated OR «plasticizer molecules» increase space/volume between chains ✓</p> <p>weakens intermolecular/dipole-dipole/London/dispersion/instantaneous induced dipole-induced dipole/van der Waals/vdW forces ✓</p>	Do not accept “«plasticizer molecules» lower density”.	2
7.	b		<p>does not degrade/biodegrade/break down «easily» ✓ occupies more space in landfills ✓ incineration produces dioxins/hydrochloric acid/HCl «which can contribute to acid rain» ✓</p>	<p>Accept “plasticizer added to PVC can be a health hazard”.</p> <p>Accept “combustion” for “incineration”.</p> <p>Do not accept simply “toxic compounds” for M3.</p>	1 max

8.	a		<p>$\text{Fe}^{3+} + \bullet\text{O}_2^- \rightarrow \text{Fe}^{2+} + \text{O}_2$ ✓</p> <p>$\text{Fe}^{2+} + \text{H}_2\text{O}_2 \rightarrow \text{Fe}^{3+} + \bullet\text{OH} + \text{OH}^-$ ✓</p>	<p>Award [1] for the net equation $\text{H}_2\text{O}_2 + \bullet\text{O}_2^- \rightarrow \text{HO}\bullet + \text{OH}^- + \text{O}_2$.</p> <p>Accept the hydroxyl and superoxide radicals represented without the radical symbols as long as there is consistent use of the radical symbol.</p>	2
8.	b		<p>$K_{sp} = [\text{Zn}^{2+}][\text{OH}^-]^2$ OR $[\text{OH}^-] = 2[\text{Zn}^{2+}]$ ✓</p> <p>$[\text{Zn}^{2+}] = \sqrt[3]{7.5 \times 10^{-18}} \Rightarrow 2.0 \times 10^{-6} \text{ «mol dm}^{-3}\text{»}$ ✓</p>	<p>Award [2] for correct final answer.</p> <p>Award [1 max] for 5.5×10^{-9} OR 6.0×10^{-9} «mol dm⁻³».</p>	2


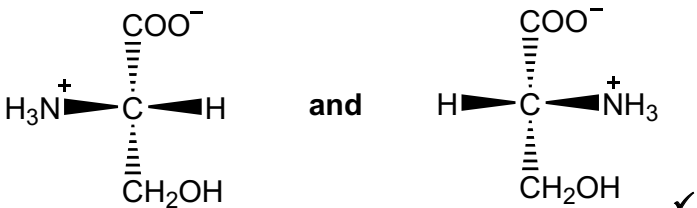
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Option B — Biochemistry

Question			Answers	Notes	Total
9.	a	i	alkenyl/ethanylylidene ✓		1
9.	a	ii	four-ring «steroidal» backbone OR fused ring structure OR three 6-membered rings AND a 5-membered ring ✓	Award [1] for a sketch of the steroidal backbone.	1
9.	b		medical uses of steroids «under physician supervision» OR detection of banned substances can be improved ✓	Accept any specific medical use. Accept answers such as “their effects «either positive or negative» are better understood”.	1

10.	a						
			pH 1.0	pH 6.0	pH 11.0		
						Charges must be shown on the correct atoms in each structure for mark. Penalize repeated mistakes once. Although question asks specifically for structures, accept condensed structural formulas, but charges must be given.	3

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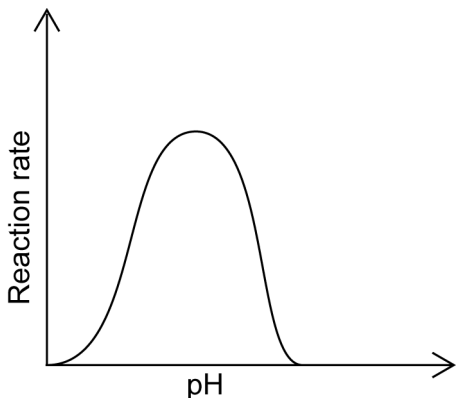
Question			Answers	Notes	Total
10.	b	i		<p>Award [2] for correct order. Award [1 max] for Leu in centre if order is incorrect.</p>	2
10.	b	ii	6 ✓	Accept 27.	1
10.	c	i		<p>Accept un-ionized or zwitterionic forms. Accept any other correct representation which clearly indicates 3-dimensional structure at chiral centre. Accept Fischer projections with the chiral carbon atom represented by crossing lines or shown as C.</p>	1
10.	c	ii	L ✓		1

11.	a		$\text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) + 6\text{O}_2(\text{aq}) \rightarrow 6\text{CO}_2(\text{aq}) + 6\text{H}_2\text{O}(\text{l}) \quad \checkmark$	<p>Accept equations for anaerobic respiration, such as $\text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) \rightarrow 2\text{C}_3\text{H}_6\text{O}_3(\text{aq})$. Ignore ATP if added as a product.</p>	1
11.	b		$n(\text{C}_6\text{H}_{12}\text{O}_6) \left(= \frac{15.0}{180.18} \right) = 0.0833 \text{ «mol» } \checkmark$ <p>«energy = $0.0833 \times 2803 =$» 233 «kJ» ✓</p>	<p>Award [2] for correct final answer. Accept –233 «kJ».</p>	2

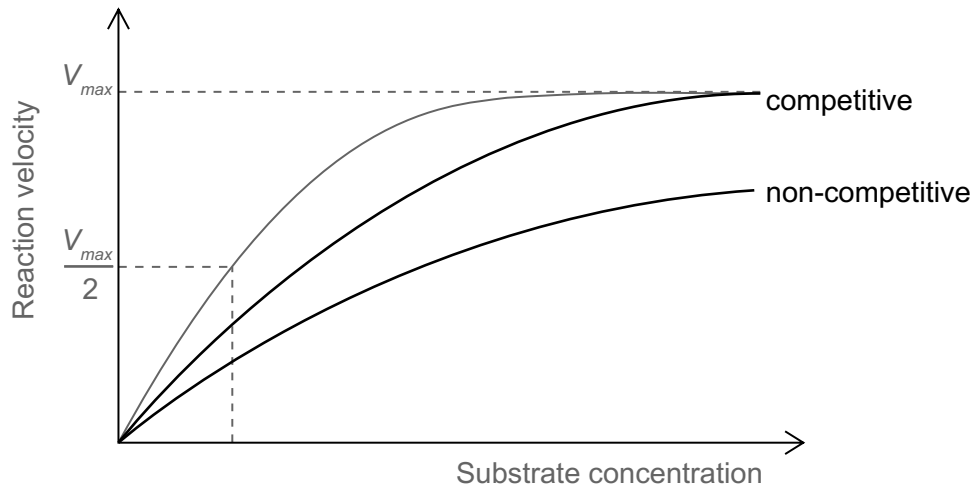
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Question		Answers	Notes	Total
11.	c	<p><i>Two advantages:</i> renewable resource ✓ broken down/digested by bacteria or other organisms within a relatively short time/quickly ✓ reduce «volume of» plastic waste/landfill ✓</p> <p>reduce use of petrochemicals OR reduce use of fossil fuels as hydrocarbon source ✓</p> <p>degrade into non-toxic products ✓</p> <p><i>Two disadvantages:</i> require use of land «for crop production» ✓</p> <p>increased use of fertilizers/pesticides «leading to pollution» OR eutrophication ✓</p> <p>might break down before end of use ✓ release of methane/CH₄/greenhouse gas «during degradation» ✓</p>	<p><i>Any two advantages for [2 max].</i></p> <p><i>M2: reference must be made to time. Do not accept “biodegradable” (since stated in question).</i></p> <p><i>Ignore any mention of cost.</i></p> <p><i>Any two disadvantages for [2 max].</i></p> <p><i>Ignore any mention of cost.</i></p>	4 max

(continued)

Question			Answers	Notes	Total
11.	d		 <p>typical curve as shown in example above ✓</p>	<p>Accept any curve with a single maximum (not just bell-shaped).</p> <p>Ignore features such as pH values on a pH scale or a pH value at maximum (if given).</p> <p>Do not penalize if curve does not touch the x-axis.</p>	1

(continued)

Question			Answers	Notes	Total
12.	a		 <p>graph showing competitive inhibitor eventually reaching V_{\max} ✓</p> <p>graph showing non competitive inhibitor not reaching V_{\max} ✓</p>	<p>Curves must be labelled and should not cross given curve.</p> <p>Penalize one mark if one or both sketched curve(s) cross the given curve.</p> <p>Award [1 max] if curves are not labelled competitive or non-competitive OR are labelled the wrong way round.</p>	2
12.	b		$\log \frac{(3.70 \times 10^{-3})}{(2.60 \times 10^{-3})} = 0.153$ ✓ <p>«pH = 4.76 + 0.153 ⇒ 4.91 ✓</p>	<p>Award [2] for correct final answer.</p> <p>Accept other method of calculation.</p>	2
13.	a		<p>A and D have one/few polar/hydroxyl/OH groups «but C has many of those» OR A and D have hydrocarbon/six-membered «carbon» rings «but C has heterocyclic/five-membered ring» OR A and D have long hydrocarbon chains/consist of mainly non-polar components ✓</p>	<p>Accept other valid similarities or differences.</p> <p>Accept “hydroxy/alcohol” but not “hydroxide” for “hydroxyl”.</p>	1
13.	b		0.47 AND chlorophyll b ✓	Accept any R_f value in the range 0.44–0.50.	1

(continued)

Question			Answers	Notes	Total
14.	a		<p>low CO₂ level causes more oxygen to be bound to the heme ✓</p> <p>high pH causes more oxygen to be bound to the heme ✓</p> <p>low temperature causes more oxygen to be bound to the heme ✓</p> <p>organic phosphates/2,3-BPG/DPG can decrease affinity for oxygen ✓</p> <p>CO decreases saturation/binds to active site/acts as a competitive inhibitor ✓</p>	<p><i>Accept reverse statements for mark.</i></p> <p><i>Award [2] if the effects of CO₂ AND pH are discussed in combination.</i></p>	3 max
14.	b		<p>contains two gamma units «instead of the two beta units found in adults»</p> <p>OR</p> <p>differs in amino acid sequence «from the two beta units found in adults» ✓</p> <p>less sensitive to inhibitors/2,3-BPG/DPG ✓</p> <p>receives O₂ from «partly deoxygenated» blood so can work at low pO₂ ✓</p>	<p><i>Accept reverse statements for mark.</i></p>	2 max

Option C — Energy

Question			Answers	Notes	Total
15.	a	i	2,2-dimethylbutane OR 2,3-dimethylbutane OR 3-methylpentane OR 2-methylpentane OR cyclohexane OR methylcyclopentane OR benzene ✓	Accept name or structural formula. Accept any mono or poly-substituted cycloalkane with a total of six carbon atoms.	1
15.	a	ii	increased branching (for acyclic hydrocarbons)/aromatic/aromaticity (for benzene)/cyclic hydrocarbon OR tertiary radicals are more stable OR higher octane rating ✓	Response in M1 must be consistent with molecule chosen in a (i).	1
15.	b	i	$\ll \frac{5470}{114.26} = \gg 47.9 \text{ kJ g}^{-1} \gg$ ✓		1

(continued)

Question			Answers	Notes	Total
15.	c		$2\text{C(s)} + 2\text{H}_2\text{O(g)} \rightarrow \text{CH}_4\text{(g)} + \text{CO}_2\text{(g)}$ OR $3\text{C(s)} + 2\text{H}_2\text{O(g)} \rightarrow \text{CH}_4\text{(g)} + 2\text{CO(g)}$ ✓	Accept a two-step process.	1
16.	a		Reagent: methanol/ CH_3OH OR ethanol/ $\text{C}_2\text{H}_5\text{OH}$ ✓ Catalyst: strong acid OR strong base ✓	Do not accept just “alcohol”. Accept any strong acid such as sulfuric acid/ H_2SO_4 . Accept any strong base such as sodium hydroxide/ NaOH .	2
16.	b		different solutions/statistical data can be compared/combined OR best ideas can be shared to arrive at global/local solutions OR acceleration of research OR discoveries become available to everyone OR improved confidence in validity of results «if multiple scientists/ research groups are involved» OR money/effort/time is not wasted duplicating work others have already done ✓	Do not accept scientists simply working together to share ideas – look for a little more detail. Accept other valid suggestions.	1

(continued)

Question			Answers	Notes	Total
17.	a		${}^{232}_{90}\text{Th} + {}^{12}_6\text{C} \rightarrow {}^{240}_{96}\text{Cm} + 4{}_0^1\text{n} \checkmark$	Accept ${}^{232}\text{Th} + {}^{12}\text{C} \rightarrow {}^{240}\text{Cm} + 4\text{n}$. Accept “4n” for “ $4{}_0^1\text{n}$ ” in any equation.	1
17.	b	i	$\lambda = \frac{\ln 2}{7.038 \times 10^8} = 9.849 \times 10^{-10} \text{ «years}^{-1}\text{»} \checkmark$		1
17.	b	ii	«3 half-lives, so» $2.11 \times 10^9 \text{ «years»} \checkmark$	Accept any value within range $2.11\text{--}2.13 \times 10^9 \text{ «years»}$.	1
17.	b	iii	produces radicals \checkmark «initiates chain reactions that can» damage DNA/ionizes biologically important molecules OR «initiates chain reactions that can» damage cells OR «DNA damage causes» mutations/cancer/apoptosis/cell death/weakening of immune system \checkmark	Do not accept just “have long half-lives so can harm living organisms”. Accept other negative biochemical and/or medical effects.	2
17.	c	i	mass of helium-4 nucleus = $4 \times 1.66 \times 10^{-27} / 6.64 \times 10^{-27} \text{ «kg»}$ OR mass of nucleons = $2 \times 1.672622 \times 10^{-27} + 2 \times 1.674927 \times 10^{-27} / 6.695098 \times 10^{-27} \text{ «kg»} \checkmark$ «mass defect = $6.695098 \times 10^{-27} - 6.64 \times 10^{-27} = 5.51 \times 10^{-29} / 0.06 \times 10^{-27} / 6 \times 10^{-29} \text{ «kg»} \checkmark$	Award [2] for correct final answer.	2
17.	c	ii	«binding energy = $\frac{\Delta m \times c^2}{\text{nucleons}} = \frac{6 \times 10^{-29} \times (3.00 \times 10^8)^2}{4 \times 1000} = 1 \times 10^{-15} \text{ «kJ nucleon}^{-1}\text{»} \checkmark$	The use of 5.51×10^{-29} and 5.00×10^{-29} will respectively give 1.24×10^{-15} and $1.13 \times 10^{-15} \text{ «kJ nucleon}^{-1}\text{»}$.	1

(continued)

Question			Answers	Notes	Total
18.			$\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HCO}_3^-(\text{aq})$ OR $\text{CO}_2(\text{g}) \rightleftharpoons \text{CO}_2(\text{aq})$ AND $\text{CO}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HCO}_3^-(\text{aq})$ ✓ «increasing $[\text{CO}_2]$ » shifts equilibrium/reaction to right ✓ pH decreases ✓	Accept " $\text{H}_2\text{CO}_3(\text{aq})$ " for " $\text{CO}_2(\text{aq}) + \text{H}_2\text{O}(\text{l})$ ".	3
19.			bond length/C=O changes OR «asymmetric» stretching «of bonds» OR bond angle/OCO changes/bends ✓ polarity/dipole «moment» changes OR a dipole «moment» is created «when the molecule absorbs IR» ✓	Accept appropriate diagrams.	2
20.	a		<i>Negative electrode (anode):</i> $\text{CH}_3\text{OH}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{CO}_2(\text{g}) + 6\text{H}^+(\text{aq}) + 6\text{e}^-$ ✓ <i>Positive electrode (cathode):</i> $\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}(\text{l})$ ✓	Award [1 max] if correct half-equations are given but at the wrong electrodes. Accept e for e ⁻ . Accept any correct half-equation with fractional coefficients.	2

(continued)

Question		Answers	Notes	Total
20.	b	<p><i>Advantage:</i> produces continuous supply of electricity «on addition of more raw materials» OR does not need to be recharged OR less hazardous if broken/exposed to the environment OR weighs less for same energy output/has higher energy density/has higher specific energy than lead-acid battery ✓</p> <p><i>Disadvantage:</i> «more» expensive OR needs constant supply of fuel OR methanol/ethanol fuel cells difficult to use in cold weather OR methanol/ethanol fuel cells produce carbon dioxide OR storage/transport of gases/hydrogen a problem in hydrogen fuel cell OR does not produce high current OR potentially explosive/hydrogen is flammable ✓</p>	<p><i>Do not accept “water is non-polluting”.</i></p> <p><i>Do not accept “weighs less” without reference to energy output/power/capacity etc.</i></p> <p><i>Do not accept “fuel cells are prone to poisoning by impurities in fuel”.</i></p>	2
21.	a	<p><i>n-type:</i> «small amount of» As/Sb/P/group 15 element added AND «extra» electrons ✓</p> <p><i>p-type:</i> «small amount of» Ga/In/B/group 13 element added AND «extra electron» holes ✓</p>	<p><i>Award [1 max] if only doping elements or only charge carriers are given.</i> Accept “group 5/group 5A/group V” for “group 15”. Accept “group 3/group 3A/group III” for “group 13”.</p>	2

(continued)

Question			Answers	Notes	Total
21.	b		large surface area «increases chance photon will be absorbed» ✓ «dye allows» absorption of a wide range of wavelengths OR dye converts most/all absorbed photons into electrons ✓		2

Option D — Medicinal chemistry

Question			Answers	Notes	Total
22.	a		<p>ring is «sterically» strained OR angles of 90° instead of 109.5/109/120° angles OR angles smaller than 109.5/109/120°/tetrahedral/trigonal planar/triangular planar angle ✓</p> <p>ring breaks up/opens/reacts «easily» OR amide/amido group «in ring» is «highly» reactive ✓</p> <p>binds to/reacts with/interferes with/inactivates transpeptidase/enzyme responsible for bacterial cell wall formation/cross-linking ✓</p>	<p><i>Do not accept “cell membrane” for “cell wall”.</i> <i>Accept “bonds to” for “binds to” in M3.</i></p>	3
22.	b		<p>Any two for [1 max] from: leads to «bacterial» resistance «of antibiotics» OR makes antibiotics less effective OR increased side effects due to larger dosages ✓</p> <p>proportion of resistant bacteria increases ✓</p> <p>destroys useful/beneficial bacteria OR destroyed bacteria replaced by more harmful bacteria ✓</p> <p>resistant bacteria pass on their resistance/mutation to next generation ✓ damage to ecosystems ✓</p>	<p><i>Accept “superbugs such as MRSA develop” but superbug must be identified.</i></p>	1 max

(continued)

Question			Answers	Notes	Total												
23.	a		<table><tr><th>Reagent</th><th>By-product</th></tr><tr><td>(CH₃CO)₂O</td><td>CH₃COOH</td></tr><tr><td>OR</td><td>OR</td></tr><tr><td>CH₃COCl</td><td>HCl</td></tr><tr><td>OR</td><td>OR</td></tr><tr><td>CH₃COOH ✓</td><td>H₂O ✓</td></tr></table>	Reagent	By-product	(CH ₃ CO) ₂ O	CH ₃ COOH	OR	OR	CH ₃ COCl	HCl	OR	OR	CH ₃ COOH ✓	H ₂ O ✓	Accept names or structural formulas for reagent and by-product. Accept IUPAC or alternative names of compounds e.g. acetic acid. Award M2 only if the by-product corresponds to the reagent.	2
Reagent	By-product																
(CH ₃ CO) ₂ O	CH ₃ COOH																
OR	OR																
CH ₃ COCl	HCl																
OR	OR																
CH ₃ COOH ✓	H ₂ O ✓																
23.	b		morphine has «two» hydroxyl «groups» AND diamorphine/heroin has «two» ester/ethanoate/acetate «groups» ✓ morphine is more polar than diamorphine/heroin ✓ diamorphine/heroin crosses the blood-brain barrier «easily» ✓ morphine is <more> soluble in blood «plasma» OR diamorphine/heroin is «more» soluble in lipids ✓	Accept converse argument throughout. Accept “alcohol/hydroxy” for “hydroxyl” but not “hydroxide”. Do not accept “diamorphine/heroin is non-polar” for M2.	3 max												
23.	c		spectrum A is diamorphine because it has a «strong» peak at 1700–1750 «cm ⁻¹ » OR spectrum A is diamorphine because it has a C=O/carbonyl (group)/ester ✓ spectrum B is morphine because it has a «strong broad» peak at 3200–3600 «cm ⁻¹ » OR spectrum B is morphine because it has a –OH/hydroxyl (group) ✓	Award [1 max] for “spectrum A is diamorphine AND spectrum B is morphine” OR correctly identified peaks associated with the correct compounds (eg. C=O for diamorphine etc.). Accept “alcohol/hydroxy” for “hydroxyl” but not “hydroxide”.	2												
24.	a		Mg(OH) ₂ (s) + 2HCl(aq) → 2H ₂ O(l) + MgCl ₂ (aq) OR Mg(OH) ₂ (s) + 2H ⁺ (aq) → Mg ²⁺ (aq) + 2H ₂ O(l) ✓		1												

(continued)

Question		Answers	Notes	Total
24.	b	<p><i>Award [1 max] for any similarity:</i></p> <p>both compounds relieve symptoms of acid reflux/heartburn/indigestion OR both increase the stomach pH ✓</p> <p>both cause diarrhoea ✓</p> <p><i>Award [2 max] for any two differences:</i></p> <p>omeprazole stops the production of acid/is a proton-pump inhibitor AND magnesium hydroxide neutralizes the «excess» acid that is present ✓ omeprazole takes longer «than magnesium hydroxide» to provide relief ✓ omeprazole is used to treat ulcers while magnesium hydroxide is not ✓</p> <p>omeprazole can prevent long term damage from overproduction of acid AND magnesium hydroxide does not OR omeprazole has a long term effect AND magnesium hydroxide has a short-term effect «only» ✓</p> <p>magnesium hydroxide affects ionic balance in the body AND omeprazole does not ✓</p>	<p><i>Award [1 max] if two or three correct points are given about one of the compounds without addressing the other compound.</i></p>	3 max

(continued)

Question			Answers	Notes	Total
25.	a		<div> <div> Example gowns/protective clothing/ shoe covers/gloves/ syringes/needles/«cotton» swabs/tools/paper/tissue/ mops OR low level waste/LLW </div> <div> AND </div> <div> Treatment storage «in shielded container» until isotope has decayed/for a period of time «then dispose as non-radioactive waste» ✓ </div> </div>	Award [1] for example AND corresponding treatment. Award [1 max] for the two examples.	2
			<div> <div> radioactive sources/ equipment OR named isotope OR intermediate/medium level waste/ILW/MLW </div> <div> AND </div> <div> storage «in shielded container in concrete chambers» underground/in caves OR storage «in shielded container» until isotope has decayed for a long period of time/for several half lives then dispose ✓ </div> </div>		
25.	b		${}_{84}^{216}\text{Po} \rightarrow {}_2^4\text{He} + {}_{82}^{212}\text{Pb}$ correct reactant ✓ correct alpha particle ✓	Atomic numbers not required for mark. Accept “α”/“ ${}_2^4\alpha$ ” for “ ${}_2^4\text{He}$ ”.	2

(continued)

Question		Answers	Notes	Total
25.	c	<p><i>Advantage:</i> selectively kills cancer cells/targets cancer cells only OR does not damage healthy cells ✓</p> <p><i>Cancer treatment:</i> melanoma OR leukemia OR rectal OR breast OR ovarian OR prostate OR pancreatic OR cancers that spread around the body/produce metastasis/dispersed cancers ✓✓</p>	<p><i>Do not accept “targets cancer”. Reference must be made to “cells”.</i></p> <p><i>Accept “skin cancer”.</i></p>	2

(continued)

Question			Answers	Notes	Total
25.	d		<p>ALTERNATIVE 1:</p> $\lambda \llcorner = \frac{\ln 2}{6.01} \gg \approx 0.115 \llcorner \text{h}^{-1} \gg \checkmark$ $\llcorner \text{remaining mass} = 5.80 \times 10^{-9} \times e^{-0.115 \times 24.04} \gg \Rightarrow 3.63 \times 10^{-10} \llcorner \text{g} \gg \checkmark$ <p>ALTERNATIVE 2:</p> $\llcorner \frac{24.04}{6.01} \gg \Rightarrow 4 \llcorner \text{half-lives} \gg \checkmark$ $\llcorner \frac{5.80 \times 10^{-9}}{2^4} \gg \Rightarrow 3.63 \times 10^{-10} \llcorner \text{g} \gg \checkmark$	Award [2] for correct final answer.	2
25.	e		<p>risk vs benefit «patient and environment»</p> <p>OR</p> <p>providing adequate information to patients about risks</p> <p>OR</p> <p>security concerns if nuclear radioactive material ended up with terrorists</p> <p>OR</p> <p>cultural resistance/superstition/lack of education</p> <p>OR</p> <p>«potential» exposure of health workers «to radioactivity»</p> <p>OR</p> <p>proper training «in radioactive hazards» not always given to workers</p> <p>OR</p> <p>proper disposal of radioactive materials ✓</p>	<p>Accept other valid ethical implications (note that risk of cancer to the patient is not an ethical issue, while risk of cancer to the health worker is).</p> <p>Do not accept “security concerns” alone – there must be some reference to an ethical implication.</p>	1

(continued)

Question			Answers	Notes	Total
26.	a		ether ✓	Do not accept “C–O–C”.	1
26.	b		Number of signals: 3 «signals» ✓ Relative integration: 6:4:1 ✓	Accept any correct ratio order.	2
26.	c	i	polarimeter ✓	Accept other alternative techniques such as “GC/HLPC/chromatography using a chiral column”. Do not accept just “polarizer”.	1
26.	c	ii	«plane-»polarized light passed through sample ✓ analyzer/second polarizer determines the angle of rotation of the plane of polarized light OR each enantiomer will rotate plane «of plane-»polarized light in opposite directions «by the same angle» ✓	Accept explanation related to other alternative techniques such as GC/HLPC/chromatography using a chiral column. Award [2] for “(+)/d rotates plane of polarization to the right AND (-)/l rotates plane of polarization to the left”.	2